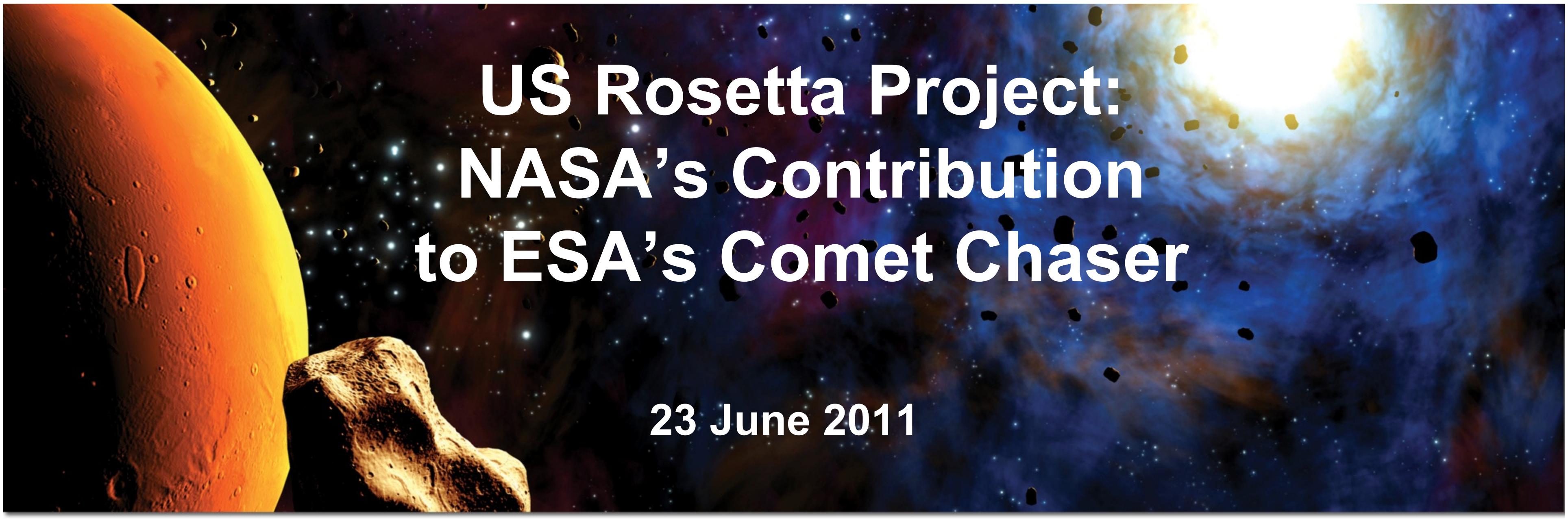
9th Annual IAA Low-Cost Planetary Missions Conference



US Rosetta Project: NASA's Contribution to ESA's Comet Chaser

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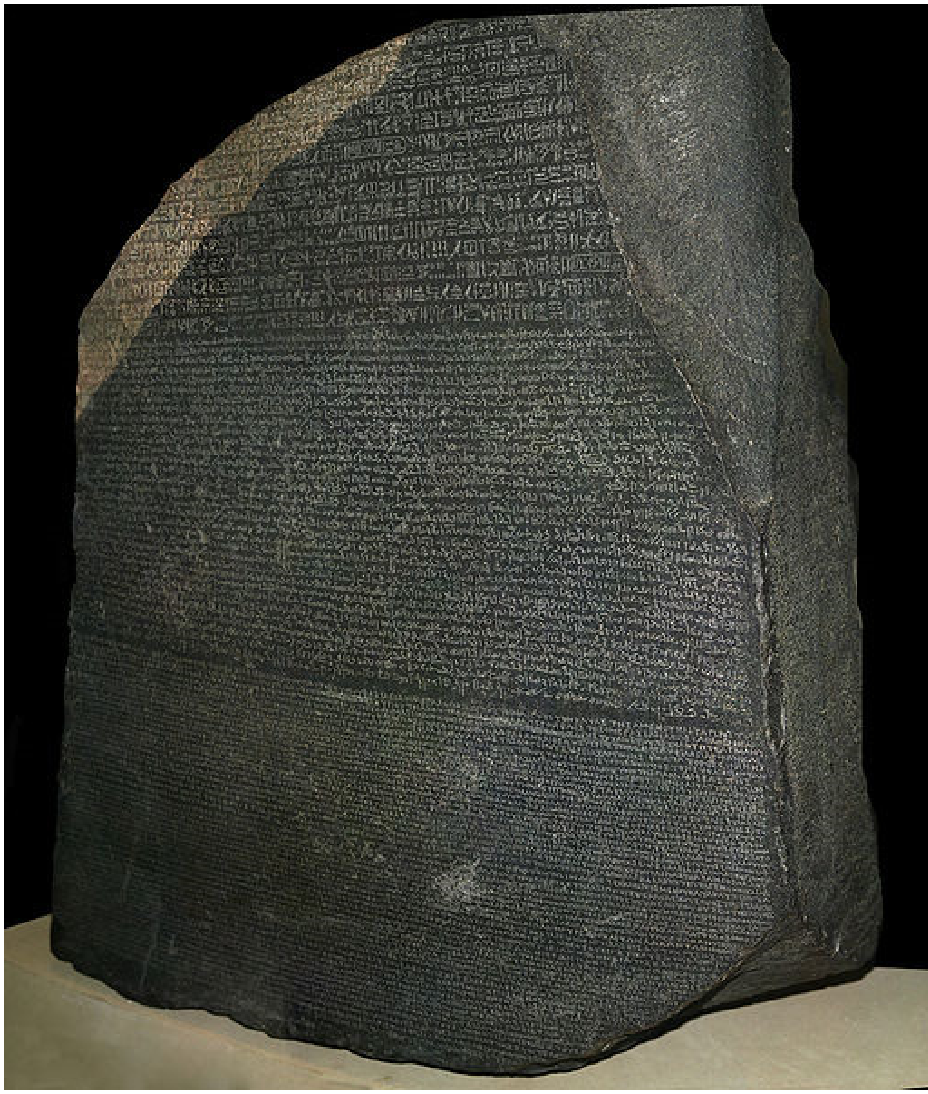
Why is the Mission called Rosetta?



In 1799 a stone was found in the Egyptian city of Rosetta featuring writing in 3 languages from 196 BC. The text was written in hieroglyphs as well as ancient Greek. It took 23 years to translate the text.

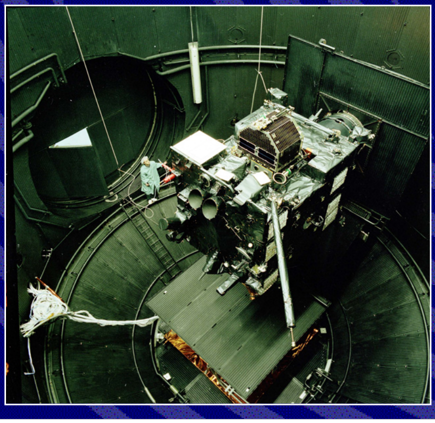
Just like the Rosetta stone allowed us to understand Egyptian hieroglyphics the Rosetta spacecraft's visit to a comet will help us understand the origins of the solar system and the planet Earth.

Why is NASA Interested in the Study of Comets?

- **Comets are preserved icy planetesimals, left over from the formation of the solar system**
  - They contain a chemical record of the conditions in the solar nebula at the time of the formation of the planets (what was its temperature?)
  - There is strong evidence that comets contain unprocessed material from the natal interstellar cloud out of which the Sun and planets formed
- **Comets maybe provided the volatile inventories of the terrestrial planets including pre-biotic molecules essential to the origin of life**
  - The Late Heavy Bombardment was most likely the result of the clearing of comets from the outer planets zone
  - This bombardment provided a volatile veneer on the terrestrial planets including water and complex organics
- **Long-period comets make up the more unpredictable fraction of the impact hazard at the Earth**
  - An understanding of cometary structure and material strengths can only be achieved through rendezvous and lander missions

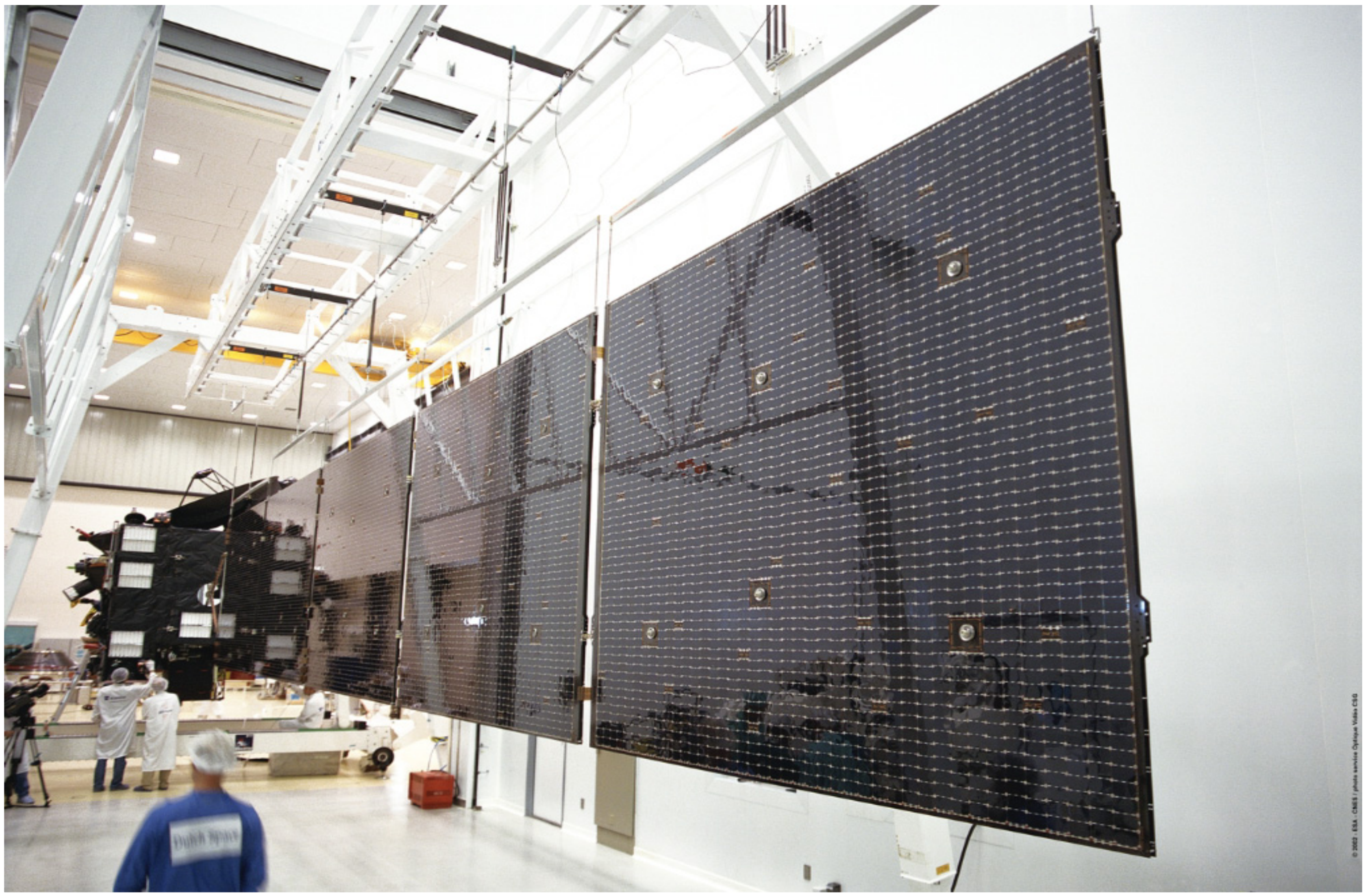
The Rosetta Spacecraft

The Spacecraft, Vital statistics



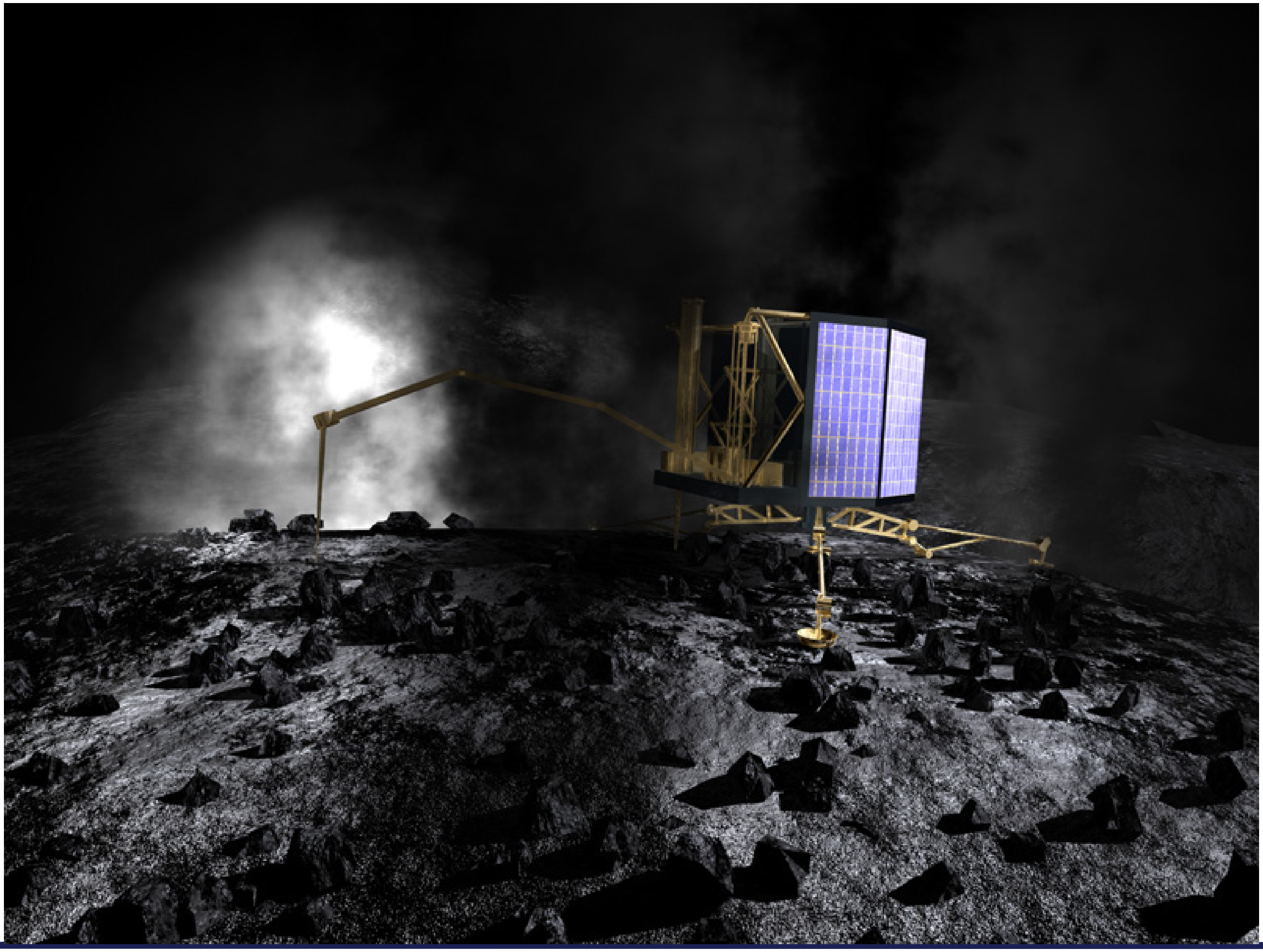
Size:	
main structure	2.8x2.1x2.0 metres
diameter of solar arrays	32 metres
Launch mass - total:	3000 kg (approx.)
- propellant	1670 kg (approx.)
- science payload	165 kg
- Lander	100 kg
Solar array output	850 W at 3.4 AU, 395 W at 5.25 AU
Propulsion subsystem	24 bi-propellant 10N thrusters
Operational mission	12 years

Rosetta is designed to operate on solar power farther than any other spacecraft



68 m2, 32m long, 22750 cells, from 8700 W close to Earth down to 440 W far away

November 2014 Comet Landing



Rosetta Science Payload

Orbiter Teams

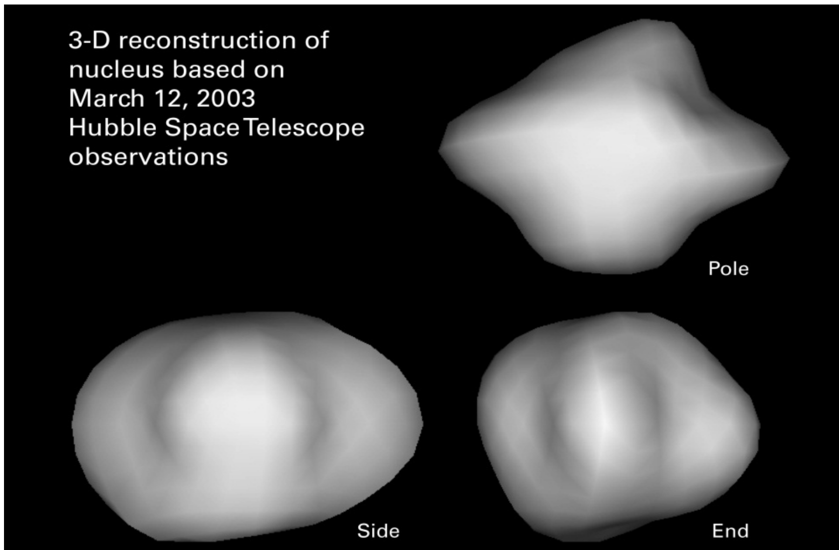
- 1. *ALICE - UV spectrometer
- 2. CONSERT – tomography/radio sounding
- 3. COSIMA – chemistry
- 4. GIADA – dust analysis
- 5. *IES - ion and electron sensor
- 6. IPA – plasma analyzer
- 7. MAP – magnetometer
- 8. MIDAS – atomic force
- 9. MIP – magnetic impedance probe
- 10. *MIRO - microwave spectrometer/radiometer
- 11. LAP – Langmuir probe
- 12. OSIRIS – camera
- 13. *ROSINA – mass spectrometer
- 14. RSI – radio science
- 15. VIRTIS – IR spectrometer

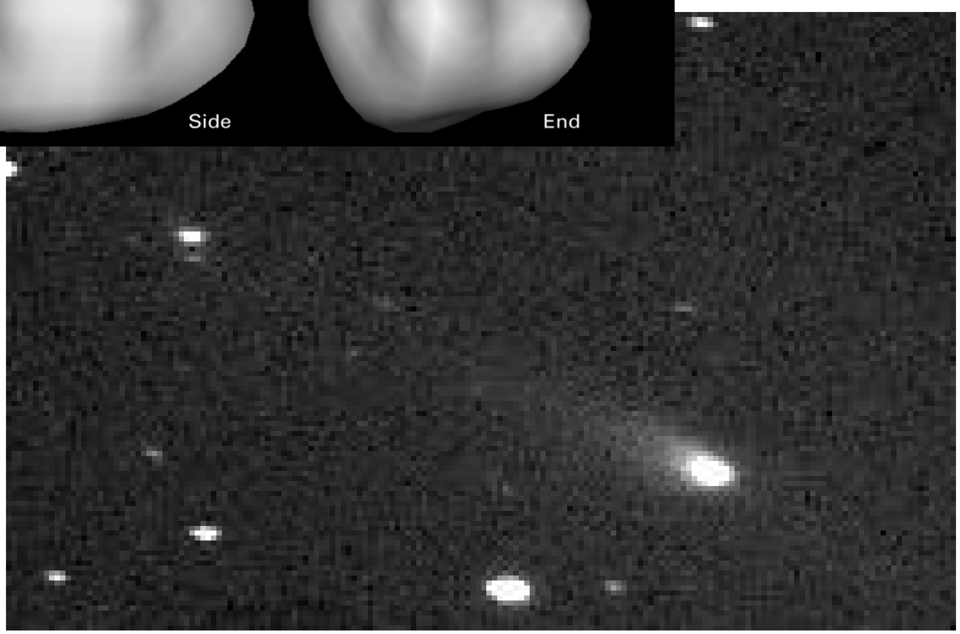
Lander Teams

- 16. APXS – X-ray spectrometer, similar to that of Mars Pathfinder
- 17. CIVA -lander visible - IR camera (omnidirectional)
- 18. COSAC – lander mass spectrometer
- 19. MODULUS – gas analyzer
- 20. MUPUS – probe
- 21. ROLIS – lander descent camera
- 22. ROMAP – lander magnetometer/material magnetism
- 23. SESAME – seismic data
- 24. CONSERT (2) – tomography/radio sounding

Legend:
US hardware contribution
US investigation contribution

The Target: Comet Churyumov-Gerasimenko

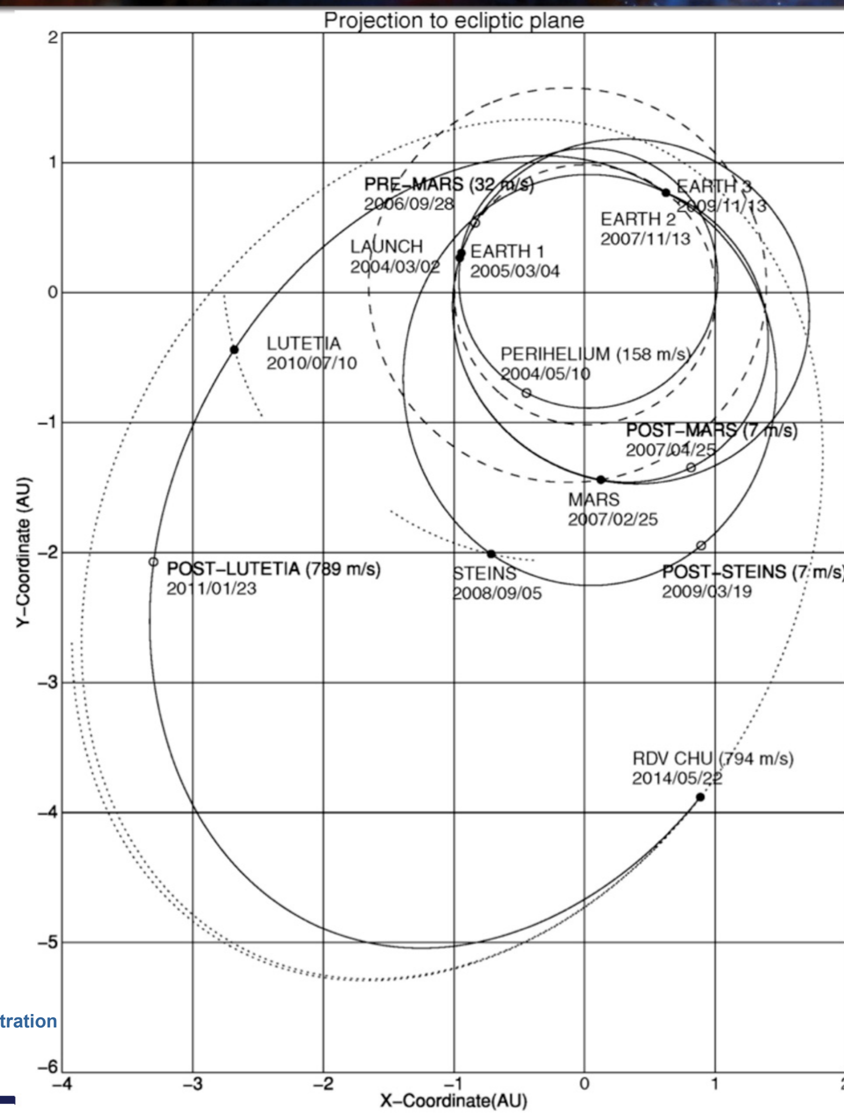




Source: CNES

- **Characteristics:**
  - Radius: 2.0 km
  - Rotation: 12.5 h
  - unknown topography and surface properties
  - temperatures
    - day ~ -50 ° C
    - night ~ -150 ° C
  - solar energy <1/10 of that near Earth
  - gravity $<10^{-5}$ g

Rosetta Trajectory



Science Targets to date

Venus
MIRO .... April 1, 2004

Earth and Moon
MIRO .... April 24, 2004
Alice and MIRO .... March 4, 2005

Comet LINEAR
Alice and MIRO .... April 30, 2004
Alice and MIRO ....May 14, 2004

Comet Catalina
MAG and LAP ....June 26, 2005

Comet Tempel 1
Alice ....June 27 – July 14, 2005
MIRO ....June 28 – July 14, 2005

Mars
Alice and IES .... Feb 25 – March 4, 2007

Jupiter
Alice ....Feb 27 – May 2007

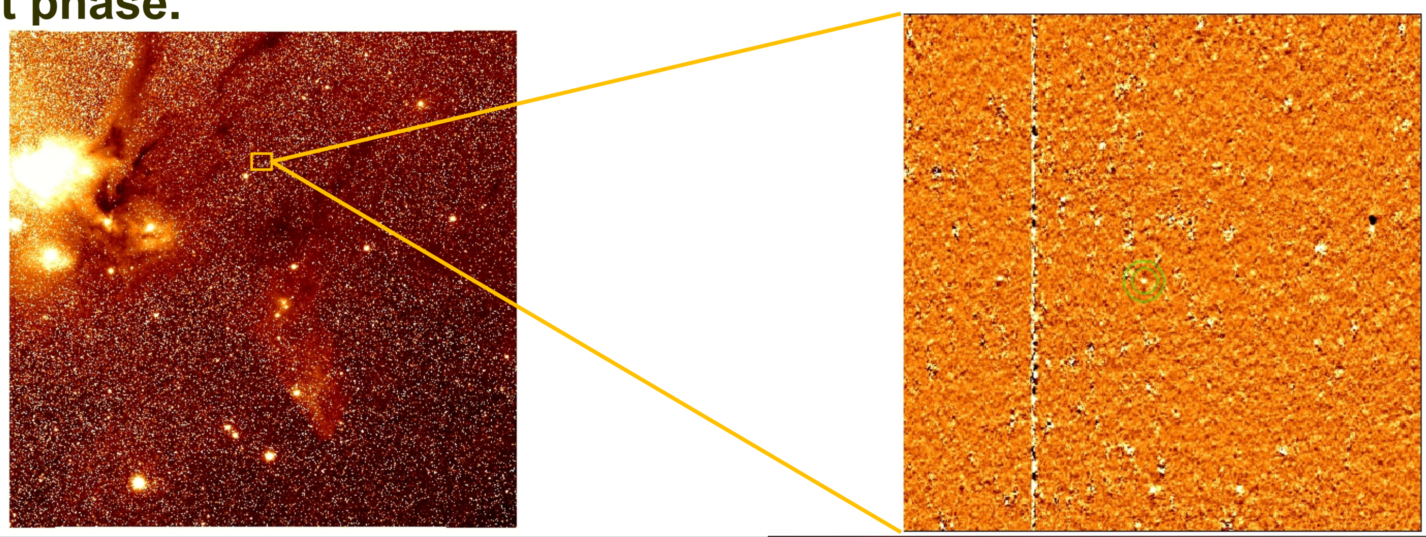
Asteroid 2867/Steins …………… Sept 3 – 2008

Asteroid 21/Lutetia ……………… July 10, 2011

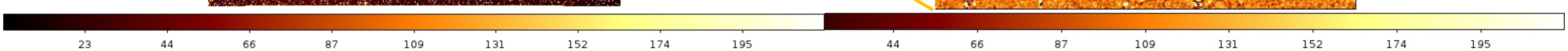
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

C-G image from Rosetta

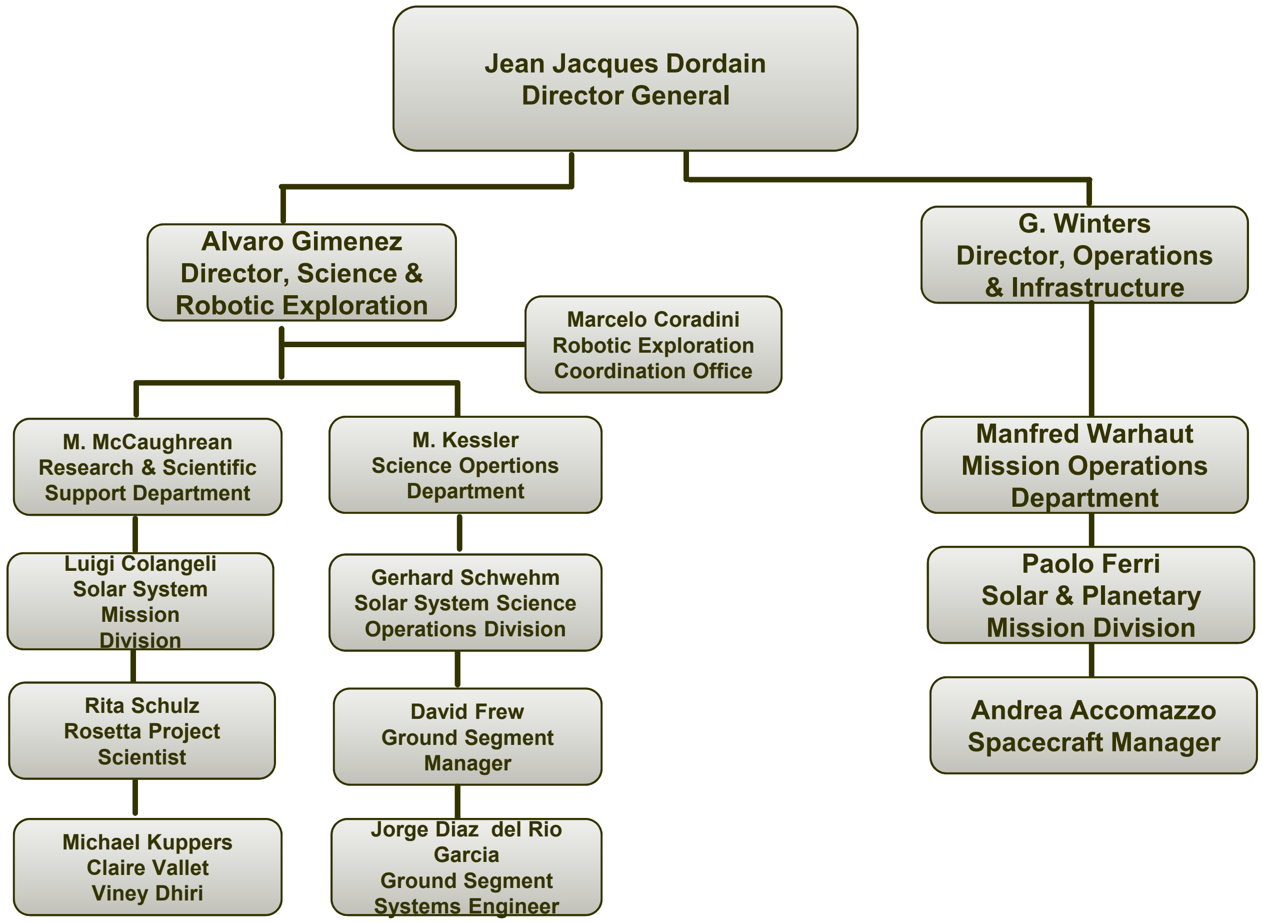
This is the most recent picture from Rosetta. Both NAVCAMs were activated to image the comet and the sky that will be seen during the approach phase. The spacecraft downlinked the images acquired by the two cameras: OSIRIS and the NAVCAMs in preparation for the comet phase.



Source: ESA



ESA Reporting Chain for Rosetta



US Rosetta Project Organization

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Art B. Chmielewski
US Project Manager

Acquisitions

Joe Espinoza – Univ. of Maryland
Richard Flores – SwRI
Jane Lee - Lockheed
Lisa Pham – University Contracts
Krandalyn Richardson – WSU
Susan Scrivner – Univ. of Arizona

Project Staff

Anna Marie Aguinaldo – Systems Engineer
Andrea Angrum - Outreach
Tracy Feehan – Resource Analyst
Padma Varanasi– DSN
Jose Macias – Mission Assurance Mgr.
Monica Martin – Staff Assistant

ALICE Instrument Team

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Joel Parker, PM – SwRI
Mike A'Hearn, Co-I (Univ of Maryland)
Hal Weaver, Co-I (John Hopkins)
Paul Feldman, Co-I (John Hopkins)

IES Instrument Team

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Ray Goldstein, Co-I (SwRI)

MIRO Instrument Team
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Mark Hofstadter, Co-I (JPL)
Mike Janssen, Co-I (JPL)
Duane Muhleman, Co-I (MIT)
Peter Schloerb, Co-I (Caltech)
Tom Spilker, Co-I (JPL)

ROSINA

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Tamas Gombosi Co-I (Univ. of Michigan)
Hunter Waite Co-I (SwRI)
Arthur Ghilmetti, Co-I (Lockheed Martin)
Dave Young, Co-I (SwRI)
Len Fisk, Co-I (Univ. of Michigan)
George Carrigan, Co-I (Univ. of Michigan)
Ed Shelley, Co-I (Lockheed Martin)

IDS
Paul Weissman
(JPL)

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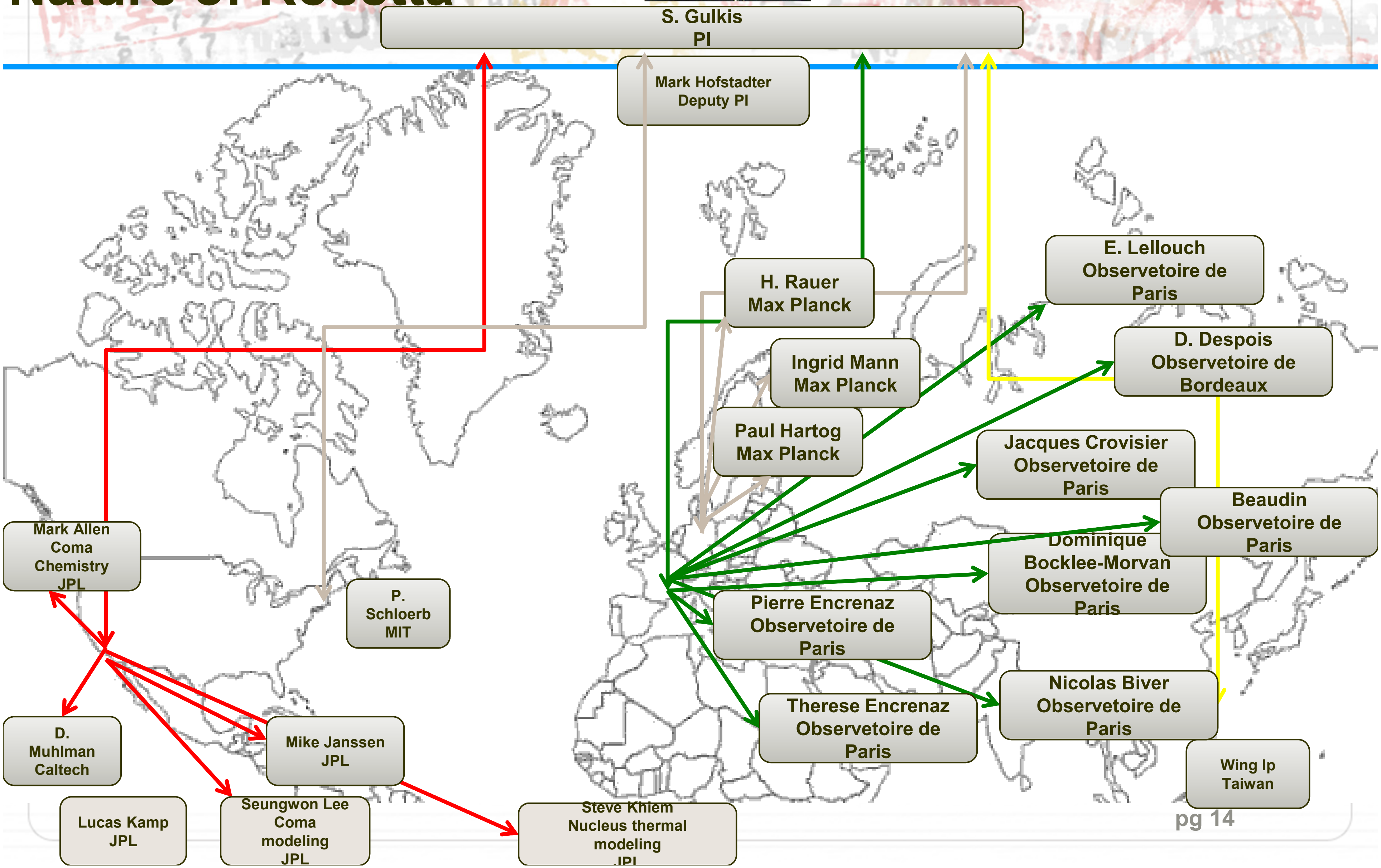
Uwe Fink, Co-I (Univ of Arizona)
Tom McCord, Co-I (Bern Flight Center)

Radio Science
John Anderson, Co-I (SwRI)
Essam Marouf, Co-I (San Jose State Univ.)

OSIRIS
Mike A'Hearn, Co-I (Univ. of Maryland)

MIRO Organization Exemplifies International Nature of Rosetta



NASA International Mission Management Lessons

- **ITAR**
  - Important to write a good LOA up-front and cover future issues
  - Staff must be well trained in export controls
  - Access to knowledgeable advisors
  - Find ways of sharing information
- **If you are a junior partner, behave like one**
  - Always give credit to the senior partner
  - Do not try to impose your processes, methods and bureaucracy
  - Don’t be a burden with knowledge, reporting, reviews
- **If you are a senior partner use junior’s expertise**
- **DSN gives new capability to any partner**

NASA International Mission Management Lessons

- ESA's has more decentralized management authority than NASA
  - Mission funding comes from different countries
  - Mission functionality is divided among many countries
    - Ground segment - Madrid
    - Operations - Darmstadt
    - Project Scientist – Nordwijk
    - Antenna – Madrid
    - Instruments – Germany, Italy, Switzerland, Great Britain
    - Archiving – Paris
- Get used to lots, and lots of emails, no phone
- Get used to meetings that start at midnight
- Develop relationships and trust

NASA Science Management Lessons from Rosetta

- **Flexible PI and Co-I selection process needed for long duration missions**
  - Over a decade scientists' interests change
  - New superstars appear on the research horizon
  - Need an easy system for updating the science team membership

- **Funds don't cross the water**
  - Must have budget reserves that allow flexibility with foreign PI's
  - Continuous effort to align the US scientists with their ESA PI's

- **Great benefit to NASA from access to 100% Rosetta data despite 10% budget contribution**

Conclusion

- NASA decided to participate in the Rosetta mission a decade ago, but it fulfills recommendations for the next decade:
  - Low cost (to NASA)
  - International cooperation
  - Visiting a small primitive body
  - Exciting, challenging objectives